

## BEST PRACTICE PROGRAMME

## Good Practice Guide

33

## Understanding Energy Use in Your Office

## Introduction

There is substantial scope for reducing energy costs in many office buildings. In offices with typical levels of energy use, the heating costs can be at least halved and electrical costs cut by one-third using readily available methods<sup>1</sup>.

Annual energy consumption and cost in office buildings varies over a wide range: total energy consumption varies from under 100 to over 1000 kWh/m<sup>2</sup> of treated floor area, and cost varies from less than £4/m<sup>2</sup> to £40/m<sup>2</sup> or more at 1991 prices.

However, the greatest potential does not necessarily lie in the buildings with the highest energy costs. For instance, some high consumers may use energy legitimately in computer rooms and the like. Conversely, even low energy offices may offer scope for cost effective improvements in

places. In order to identify where the potential savings are highest, you need to know how energy is currently being used in your office buildings.

This Guide outlines how you can come to terms with the pattern of energy use in your offices. More comprehensive information on how to assess your energy use is available in the CIBSE Applications Manual on Energy Audits and Surveys<sup>2</sup>.

## Typical consumption profiles

Each office uses energy in different ways.<sup>1</sup> Figure 1 shows example breakdowns of annual energy use and cost for four typical office buildings:

- Type 1 Naturally ventilated, largely cellular;
- Type 2 Naturally ventilated, largely open plan;
- Type 3 Air conditioned, largely open plan;
- Type 4 Prestige air conditioned with computer suite, restaurant etc.

## ENERGY

## EFFICIENCY

## IN OFFICES

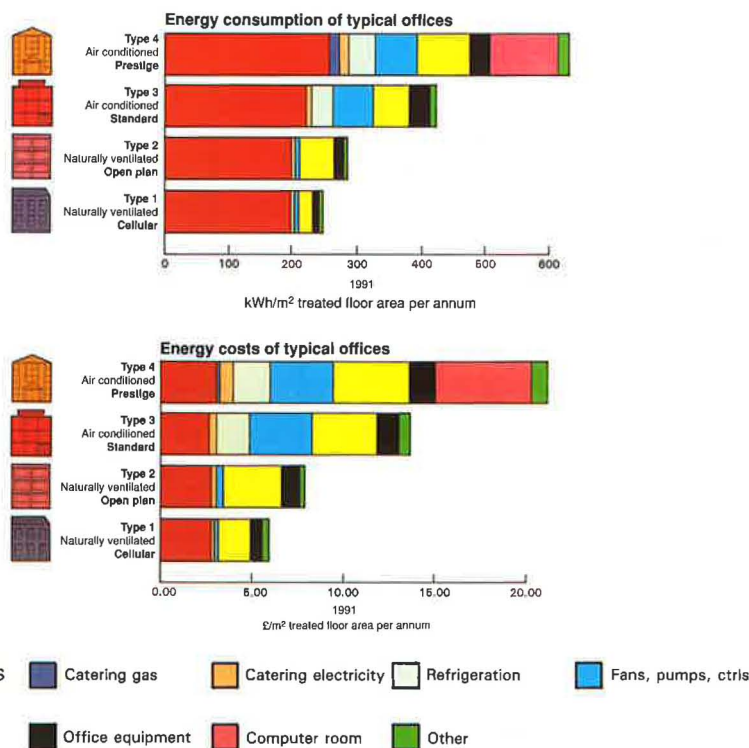


Figure 1. Annual energy consumption and cost in four typical offices

These illustrations are based on averages from the existing stock: some offices can use twice as much, sometimes more in some categories. On the other hand, good practice offices can use less than half, as Good Practice Case Studies<sup>3</sup> demonstrate. Using the information in this Guide, you can build up a picture of how energy is used in your office buildings and compare with these figures and the more detailed data given in Energy Consumption Guide 19<sup>1</sup>.



**Energy Efficiency Office**  
DEPARTMENT OF THE ENVIRONMENT

## UNDERSTANDING ENERGY USE

### Fossil fuel consumption

Oil and gas are used primarily for heating, with smaller amounts for hot water and for catering kitchens. Average levels of annual consumption are similar for each of the different building types, typically being about 200-250 kWh/m<sup>2</sup>, and costing around £3/m<sup>2</sup>.

### Electricity consumption

Electricity use varies more widely than fossil fuel use, the most significant influences being:

- open plans, where lights are usually left on for longer periods than in cellular offices, especially in deep plans which normally require more permanent artificial lighting.
- air conditioning: where fans and pumps generally use more energy than refrigeration, particularly in all-air systems.
- mainframe computer rooms and their air conditioning.

Energy use by general office equipment is significant, but not always as high as people expect.

Larger offices often contain more equipment and operate for longer hours, adding to energy use. However, their higher consumption and more continuous loads give them more advantageous tariffs, which slightly lowers the cost paid for each unit of electricity.

Many people associate energy efficiency primarily with heating and insulation. However, in most offices electricity bills are higher than gas or oil bills, often by a large margin, and understanding of electricity use is therefore particularly important. Electricity costs can vary from about £2/m<sup>2</sup> to over £40/m<sup>2</sup>, compared to fossil fuel costs of around £3/m<sup>2</sup>.

### FUEL CONSUMPTION DATA

You will need to obtain all the fuel bills for at least one year: these will normally be monthly. Small buildings, however, are sometimes billed quarterly, often with alternate quarters based on estimated readings only. This will not usually give enough information and it will be best to arrange for regular meter readings at monthly intervals.

If you use stored fuels, such as coal, oil, and LPG, then there may be little direct relation between delivery and consumption and you will need to set up systems of measurement. Chapter 5 of the CIBSE Applications Manual on Energy Audits and Surveys<sup>2</sup> outlines how to read bills, measure fuel consumption and extract useful data.

### ENERGY FINGERPRINTS

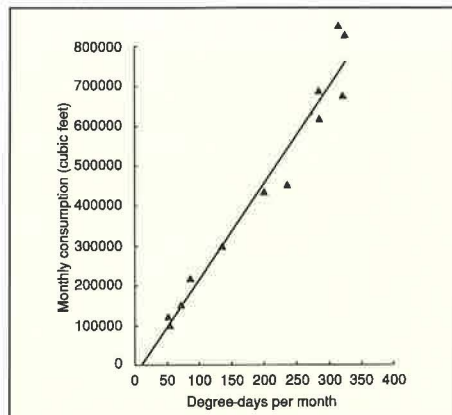
A lot can be learned just from looking at the monthly pattern of consumption of each fuel.

### Heating fuel consumption

For heating fuel, the most common device is the degree-day plot<sup>2, 4</sup>. Degree-days are a measure of the requirement for heating over a period of time due to outside air temperature. The demand for heating will be high when the outside temperature is low; the degree-day figure will be correspondingly high. In a warmer period, the heating demand will be less, and the degree-day figure will be lower. If the heating system is well controlled, there should be a linear relation between the energy used for heating and the number of degree-days — as the number of degree-days increases, the heating energy

consumption should increase at a steady rate. The degree-day plot is a graph which is produced by plotting monthly fuel consumption vertically and monthly degree-days for your area horizontally.

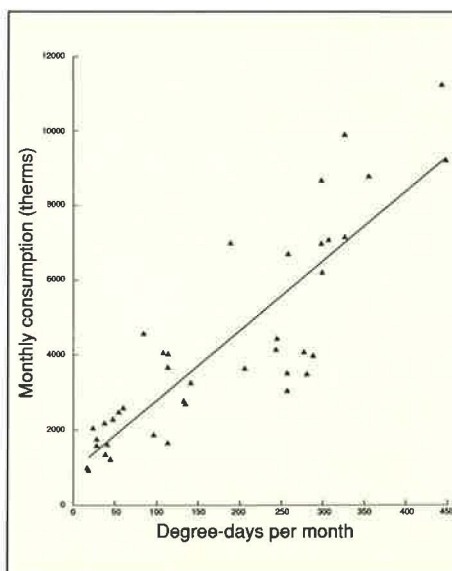
Degree-day figures are published in the Energy Efficiency Office's Energy Management magazine. They are set to a standard format for different areas of the country. More detailed information can be obtained from a variety of organisations.



**Figure 2. A good degree-day plot for heating only**

Figure 2 shows a good degree-day plot. The closeness of the data points to the trend line indicates that the heating system is consistently controlled in accordance with the weather. This is a good start, but further investigation may nevertheless show scope for savings.

Figure 3 shows a poor plot, with a large intercept, a wide scatter of data points, and consumption which increases disproportionately as the weather gets colder. In this example, the problem was traced to faulty damper controls on the central air handling plant, installed to provide "free cooling" but instead giving excessive wintertime ventilation!



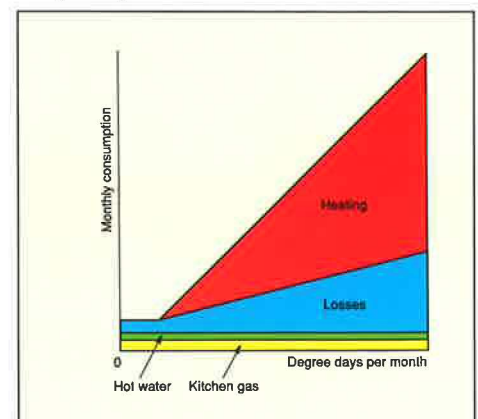
**Figure 3. A poor degree-day plot for heating and domestic hot water**

The intercept of the degree-day plot (the energy consumption at zero degree-days) is often taken as an approximate indication of the base load. This is usually attributable to standing losses from the heating plant, and energy consumption for domestic hot water and catering. The value of the intercept can also be affected by other variables, but a discussion is beyond the scope of this Guide.

Where possible, separate components should be individually metered, with gas sub-meters on supplies to catering kitchens, for example. This will help to identify the energy used for different purposes more accurately.

Figure 4 shows how the fuel consumption for different purposes combines on an idealised degree-day plot. In this example, fuel from one meter is being used for catering, domestic hot water and space heating. The graph shows the fuel use for:

- kitchen gas; a constant level throughout the year
- domestic hot water; a constant level throughout the year
- losses from the boiler and heating plant; in the winter when the boiler is used more, the losses go up, but note that some of these 'losses' may actually result in useful heat gains to the building
- space heating within the building; as the weather gets colder, the heating energy use goes up.



**Figure 4. The build-up of an idealised degree-day plot**

### Monthly electrical consumption

Monthly electricity consumption is usually much more uniform than heating fuel consumption, although some components show seasonal variations, in particular:

- more lighting in winter in cellular offices and in offices of other types where there is effective lighting control;
- more refrigeration in summer in air-conditioned buildings.

### Electrical sub-meters

If possible, you should try to sub-meter electricity to distinct main end uses, and in particular:

- catering kitchens
- computer rooms
- computer air conditioning
- main plant items, particularly chillers and large fans.

You may be lucky enough to have these already, in which case make sure that they are read at regular intervals (either manually or automatically via a BEMS), and the results recorded and acted upon.

### Using metered information

Too often data which is available from meters and BEMS contains a wealth of information yet is not used effectively by management. For example plant and control problems often first become apparent from an increase in energy consumption which is quickly noticed if the appropriate records and charts are kept. Techniques such as CUSUM<sup>4,6</sup> can give prompt alerts, both for the building as a whole and for individual sub-meters.

In computer rooms, if both the air conditioning plant and the computer equipment are separately metered (often a simple task at the design stage), dividing the energy use for air conditioning by the energy used by the computers can give a useful index of performance. If the ratio is much over 0.6, it is likely that the air conditioning is not dealing with the heat gains from the computers efficiently, and there is probably scope for improving the control and management of the air conditioning.

### BUILDING UP THE PICTURE

Not everything can be determined by working from meter readings alone. Suitable metering points will not always be available for concentrated loads, and energy use by dispersed items — for example lighting and office equipment — will not normally be separable in this manner. In these circumstances, the pattern will need to be built up from information on the electrical requirements of the equipment and its average hours and intensity of use.

It is not difficult to schedule every item of equipment and lighting in an office. However, the power consumption of each item may be uncertain, as in many cases the average level of power usage may be different from the value given on the nameplate. Typical rules of thumb for the ratio of actual power consumption to the declared ratings on nameplates are:

- fans and pumps 80%
- fluorescent and discharge lamps (to include control gear) 120%
- tungsten lamps 100%
- office equipment average 30%

Average hours of use can be determined from plant schedules and from careful observation for items under user control.

### The overall energy consumption, ie

Number of units

×

Average power consumption

×

Weekly hours of use

×

Number of weeks in billing period

can then be built up rapidly on a computer spreadsheet and reconciled with the metered data.

By using both measured data from meters and estimates of energy use by equipment, it is possible to get an overall picture of how energy is used in the office. The more information that is available, the better the picture will be.

### COMPARISON WITH NORMS

Most norms divide annual energy consumption by unit floor area (nett, gross or treated). In this Guide we use treated area.

Comparisons can be done both at a whole building level and for individual end uses, such as lighting. Some values for typical offices are given on the front page of this Guide and in Energy Consumption Guide 19<sup>1</sup>.

As simple working rules and excluding car parks, attics, and large stores, ratios of treated to gross and nett lettable area for reasonably space efficient offices will be in the region of:

	Treated to gross	Nett to treated	Nett to gross
Type 1	95%	80%	76%
Type 2	95%	80%	76%
Type 3	90%	80%	72%
Type 4	85%	80%	68%

These figures should be used for initial checks only: for more detailed comparisons, measurement of your own buildings is recommended. Individual offices can easily deviate by  $\pm 5\%$  from these norms, and values for floor areas obtained from files or colleagues are often inaccurate.

### Short notes on the measurement of Floor Area

Gross	Total building area measured inside external walls
Nett	Gross area less common areas and ancillary spaces. Agent's lettable floor area
Treated	Gross area less plant rooms and other areas (eg stores, covered car parking and roof spaces) not directly heated.

## Understanding how energy is used in your building is the first major step to achieving energy savings.

- Collect your energy use and cost data for the past year or more.
- Obtain or measure the floor area of your buildings. If only gross or nett areas are available, use the conversion factors on this page for initial estimates.
- Consider the overall annual electricity and fossil fuel consumption, and if the monthly consumption pattern relates sensibly to the weather and to the pattern of use.
- Try to understand features of your buildings which might cause the consumption levels to be particularly high or low. If your electricity is on a Day/Night tariff this information can be invaluable in helping to estimate night-time loads such as computer suites.
- Concentrate at first on the buildings or features which are particularly high energy consumers or offer the greatest potential for energy saving.
- If necessary, install and read meters to check the amount and pattern of energy consumption by major individual items, such as computer rooms, computer air conditioning, kitchens, chillers and large fans.
- Regularly review the information provided by meters.
- Prioritise the measures. Simple, highly cost effective measures can sometimes create cash reserves from utility budgets to help finance subsequent projects.
- Make use of opportunities. The best time to implement energy saving measures is on the back of an essential project, for example maintenance, alteration, re-equipment and refurbishment. Don't lose the chance in the rush.
- Keep it simple. Don't use any more, or more complex, technology than necessary to solve the problem effectively. Don't create unnecessary maintenance or management burdens.
- Refer to other EEO Good Practice Guides as necessary (see page 6).
- Obtain professional advice if you require it.

## UNDERSTANDING ENERGY USE

Figure 5, taken from an open plan office with natural ventilation and good daylighting, shows a clear dip in the four summer months only but little effect at other times, suggesting that the daylight-linked lighting controls are not fully used at other times of the year.

Figure 6 indicates better control, with a more gradual decline in spring and increase in autumn. In spite of the drop in lighting load, the overall electrical consumption of this building rises again between May and August, when comfort cooling systems operate.

If electrical consumption peaks in spring and autumn, then there may well be a problem with simultaneous heating and cooling, which will need investigating.

### Electrical day/night ratios

Day/night electricity tariffs will normally be advantageous for offices with computer rooms and other substantial loads which run around the clock. Check that you are on the best tariff: your electricity supplier will advise you on request and can also arrange any necessary demand profile recording.

Monthly bills which show separately the day and night units can greatly help you to understand where your electricity is going. First check the length of the night charging period: usually it is seven hours a day from 00.30 to 07.30 am, but sometimes it includes the whole weekend.

If you have a computer suite which operates day and night, the rate of night-time electricity consumption will help you to determine how much power it is using. Estimate how much electricity is used at night for other items such as controls, telecoms, external and security lighting, vending machines, office equipment left on and early morning plant start. These should normally account for less than 10% of the overall electricity consumption. The remainder of the night electricity use should then be accounted for by the computer suite, which will also draw power at a similar rate during the day.

If the level of electricity use at night seems high and difficult to account for, it may indicate that equipment and lights are being left on unnecessarily, or that plant is operating when it should be idle.

### Hourly demand profiles

Hourly (or more commonly half-hourly) electrical demand profiles may be obtained using portable recorders: sometimes they may be available directly from existing electronic Building Energy Management Systems (BEMS). Recorders can be purchased or hired, and may sometimes be lent for short periods by the electricity supply companies to help determine the most appropriate tariff for your building. The recorders may be attached to the building's main electrical supply or to individual sub-circuits or plant items, for example a computer room, a chiller, or an air conditioning fan.

Figure 7 shows how a demand profile is built up from its constituent parts. Note that in this figure, and also in figure 1, the computer room value

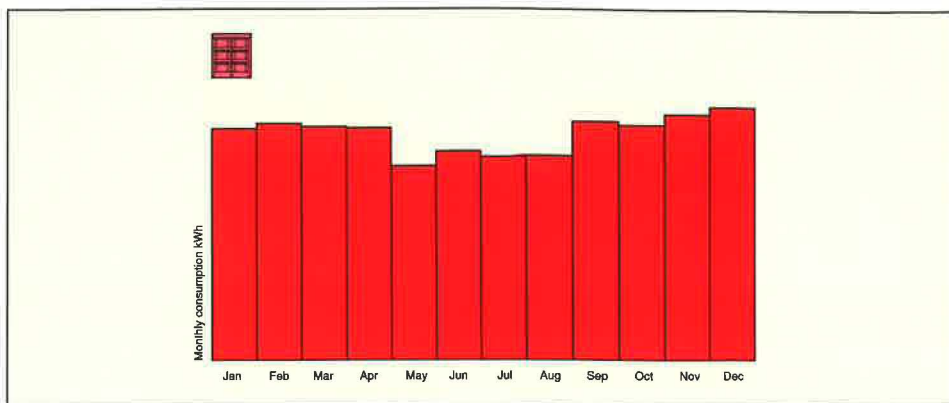


Figure 5. Monthly electrical consumption of an open plan naturally ventilated building with good daylighting

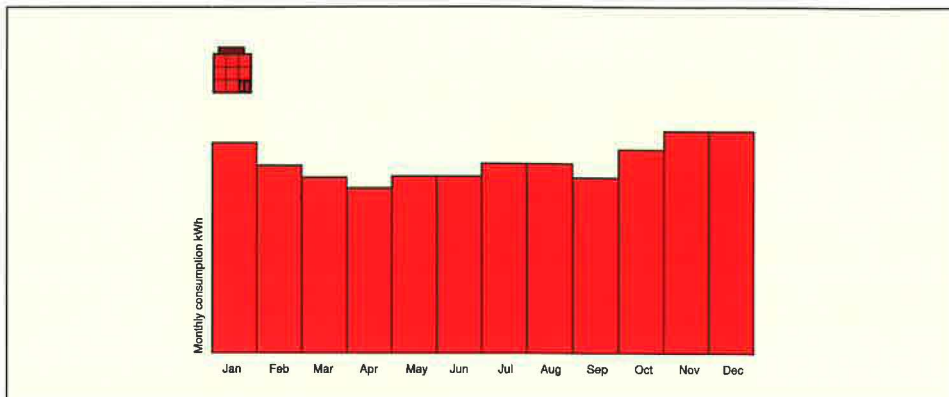


Figure 6. Monthly electrical consumption of an open plan building with automatically controlled lighting and partial air conditioning operated in summer only

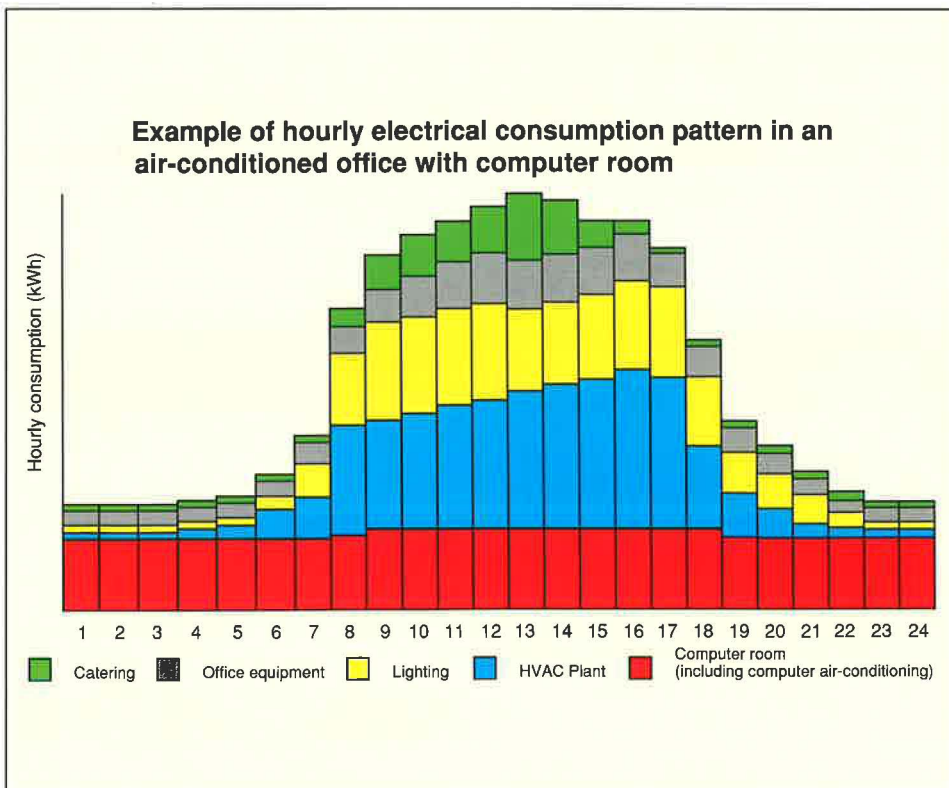


Figure 7. Typical hourly electrical demand profile showing various uses

includes both the computer equipment and the associated air conditioning plant. Of course, a recorder on the main supply will only give you the totals, but often more information can be obtained

either from the sub-feeds or from monitoring over a longer period. For example, monitoring over the weekend can give you a good idea of the true baseload.

## Tariff structures

Fossil fuels are normally charged for by quantity only, sometimes on a sliding scale or negotiated according to quantity, with a standing charge for gas.

Payment for electricity is more complex in all but the smallest office buildings, or where electricity is re-charged from landlord to tenant. Most users purchase electricity from their local regional electricity company in the 'franchised' sector of the market. Further information on purchasing energy supplies is given in the IPS Energy Guide 5.

Tariffs fall into 3 main categories.

**Block tariffs** include a standing charge plus a charge per unit consumed. The unit rate may be fixed or vary by time of day or day of the week.

**Seasonal Time Of Day (STOD) tariffs** are similar to block tariffs but may include several different unit rates in a single day and these may vary from day to day and month to month.

**Maximum Demand (MD) tariffs** have a standing charge plus unit charges which may vary with time, in particular from day to night. In addition, Maximum Demand charges are levied; these are variable monthly charges that depend on the maximum amount of electrical power drawn (in kVA or kW) in any 30-minute period during the month.

Further principles apply to STOD and MD tariffs.

- Power may be supplied at low or high voltage; in the latter case, the customer provides the sub-station and transforms the power to the voltage required. High voltage supplies are about 9% cheaper but there is a substantial capital cost involved.
- Reactive Power Charges may be applied when the power factor falls below a figure set by the supply company (usually 0.95 or 0.90). The power factor — a figure between zero and 1 — is a measure of the useful energy extracted from the power taken from the supply; the higher the figure, the better the performance.
- An Availability Charge is usually applied; this is a monthly charge which depends on the agreed supply capacity. The agreed figure applies for five years from the date of completion of the building or the date of last increase.
- The unit rates may vary according to the cost of primary fuel at the power stations.

The changes in the electrical supply industry have also led to new options for large electricity consumers. Consumers with a peak load of over 1 Megawatt may purchase electricity from any regional electricity company or other supplier in the 'non-franchised' sector of the market. From 1994, the threshold will be reduced to 100 kW, and from 1998, all customers will be able to purchase electricity from any supply licence holder over the existing distribution facilities. This 'non-franchised' sector has become extremely competitive, with the largest users making savings of up to 20% under short-term agreements.

The available tariffs and suppliers should be reviewed from time to time to make sure that you are using the most appropriate for your building's needs. For example, growth in computer rooms and other equipment which remains on overnight makes tariffs with low rates at night more economical for increasing numbers of office buildings. Computer based tariff software can be used to help evaluate which is the most appropriate tariff to use.

Having selected the best tariff option, costs can be kept down by considering all components of the bill. Although unit charges predominate, the other components are not insignificant and usually account for between 15% and 30% of the total costs.

- Unit charges can be reduced by minimising all consumption, particularly during periods of peak charges; this applies to all tariffs.
- Availability charges can be minimised by estimating electrical requirements carefully, containing growth within the availability limits, and reducing the limits when allowable.
- Maximum Demand charges are applied by most authorities between November and February only, and one should minimise the peak electrical loads during this period. These often occur around lunchtime when catering loads occur together with office lighting, equipment and air conditioning. It is often possible to reduce these by energy management, kitchen equipment selection, and avoiding electric boosting of the hot water temperature for large dishwashers.

- Reactive Power charges can be avoided by installing power factor correction equipment, either to individual devices or with central capacitors automatically switched in banks.

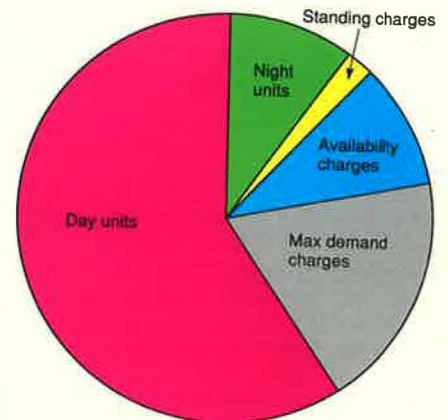


Figure 8a shows the composition of electrical charges for an electrically heated, naturally ventilated office

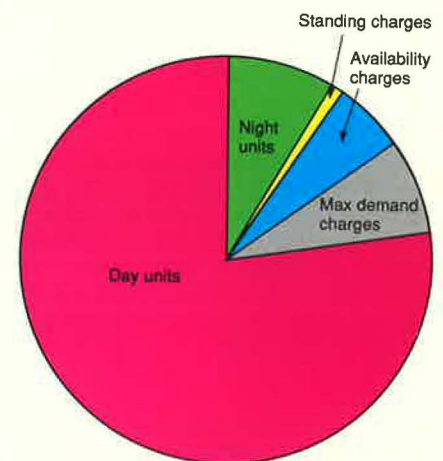


Figure 8b shows the composition of electrical charges for an office with a large computer room

### Considering the Priorities

Energy efficiency in offices is not only — or often even mainly — about heating; electricity costs usually predominate, and offer good scope for cost effective energy savings.

### Heating

For heating itself, better insulation is not the whole story. Many buildings, including well insulated ones, cost more to heat than they should owing to inefficiencies in plant, control and management.

Improvements can be made by:

- good control and management of plant to minimise running hours and avoid standing losses;
- ensuring that heating plant is not over-sized;
- using separate plant for domestic hot water heating, especially in summer (possibly using point of use water heaters);
- installing condensing boilers which are well controlled so that they operate at the high levels of efficiency which are possible?

### Air Conditioning

In air-conditioned offices, people often regard chiller efficiency as paramount. However, with all-air systems the fans generally cost more to run, and attention to fan power and control can be more rewarding. Excess running hours often lead to unseen — and often undetected — waste. Hours-run meters on important items of plant can be helpful and parts of the office which are regularly used outside normal hours should be separately zoned and controlled.

### Mainframe

Mainframe computer suites (the computers plus associated air-conditioning) can sometimes account for more than half the entire energy bill. The air-conditioning often runs inefficiently and offers scope for substantial savings through improved control and management.

If possible, power supplies to the computer and its air-conditioning should be separately metered and regularly monitored. Unified control should be considered for installations made up from independent packaged units.

### Lighting

Lighting can be the largest single item of energy cost, varying over a wide range depending upon installed power and hours of operation. In cellular offices people can easily use available daylight and should be encouraged to do so. In open planned offices the situation is more complex and the lights often tend to stay on all day<sup>8,9</sup>. New lamps, reflectors and controls can often give major savings, particularly for lights which burn for long hours, necessarily or otherwise.

### Office Equipment

Although office equipment often uses less energy than people expect, leaving it on unnecessarily — and particularly overnight — should be discouraged. Purchasing decisions should take account of energy requirements: some brands and types of equipment are considerably more energy efficient than others, and their lower heat output also helps reduce both the need for air conditioning and the cooling loads it has to serve.

### Management

Good management is essential. Energy efficiency is not an end in itself, but a reward for meeting the organisational and user needs in an effective and professional manner. Important aspects include:

- matching performance standards and operating hours to user needs;
- regular checking of control functions;
- regular reviews of fuel bills and sub-meter readings;
- good maintenance of plant;
- attempting to site office equipment with high heat outputs in places where it does not unnecessarily increase cooling loads or the need for air conditioning, for example in areas with separate local air extract systems.

If you have a Building Energy Management System (BEMS), do not leave it to its own devices: treat it as a management tool. The BEMS itself needs to be monitored to ensure that it is operating at full effectiveness.

### Fuel Costs

Finally, you may be paying more for your fuel, and particularly your electricity, than you should. More suitable tariffs may be available and you may also be able to take steps to improve power factors or Maximum Demand profiles.

### REFERENCES

1. Energy Consumption Guide 19: A technical Guide for owners and single tenants. Energy Efficiency Office 1991.
2. CIBSE Applications Manual AM5: Energy Audits and Surveys Chartered Institution of Building Services Engineers, London 1991.
3. Good Practice Case Studies numbers 1, 13-21 — Energy Efficiency in Offices. Energy Efficiency Office 1989-1992.
4. Fuel Efficiency Booklet 7: Degree Days. Energy Efficiency Office 1987.
5. The IPS Energy Guide. Energy Efficiency Office 1991.
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7. CIBSE Applications Manual AM3: Condensing Boilers Chartered Institution of Building Services Engineers, London 1989.
8. BRE Digest 272. Lighting Controls and Daylight Use. Building Research Establishment 1983.
9. BRE Information Paper 5/87. Lighting Controls: An essential Element of Energy Efficiency. Building Research Establishment 1987.

### OTHER PUBLICATIONS IN THE BEST PRACTICE PROGRAMME

#### Good Practice Case Studies

- 1 Policy Studies Institute
- 13 NFU Mutual and Avon Group HQ
- 14 Cornbrook House
- 15 Hempstead House
- 16 Heslington Hall
- 17 Hereford & Worcester County Hall
- 18 Quadrant House
- 19 South Staffordshire Water Company
- 20 Refuge House
- 21 One Bridewell Street

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- 19 Energy Efficiency in Offices. A technical Guide for owners and single tenants.